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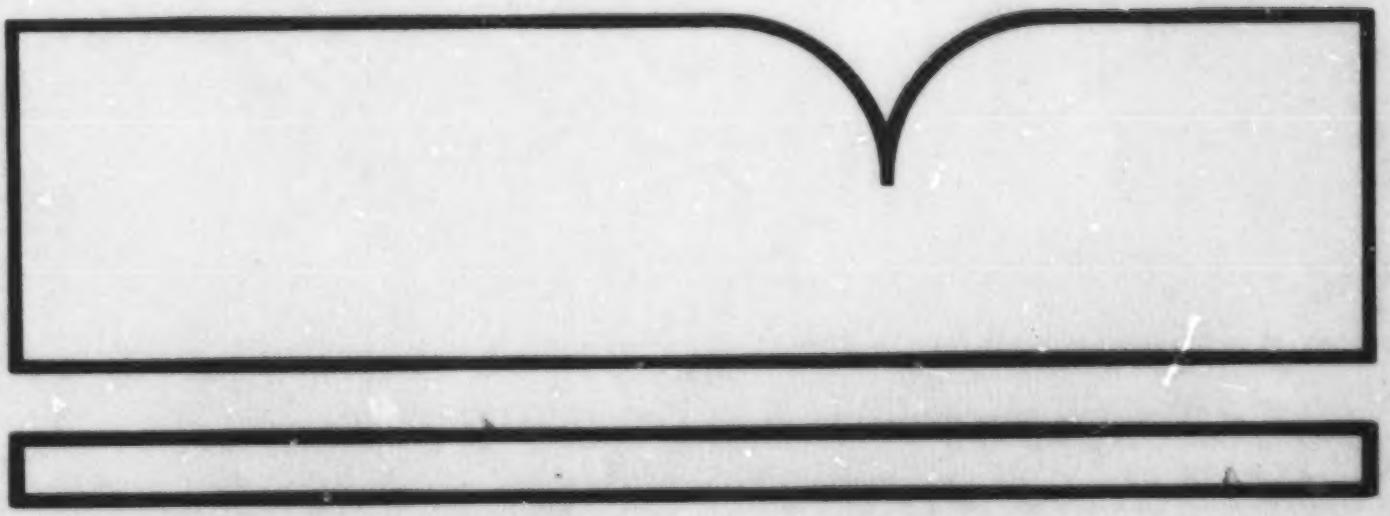

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16. ABSTRACT
The multiple-use aspect of lakes and reservoirs in recent years has been a source of growing concern. A panel discussion focussed on: the increased public pressure to use lakes and reservoirs and the attendant technical and biological problems that have evolved; the viral element of this water quality concern; the management implications and recommendations for protecting swimmer's public health; the potential and observed microbial effects of fecal contamination associated with land uses in nearshore areas of lake and estuarine environments.

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PUBLIC HEALTH MICROBIOLOGY OF LAKES AND RESERVOIRS

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INTRODUCTION

The multiple use aspect of lakes and reservoirs in recent years has been a source of much growing concern over microbial water quality and Edwin Geldreich described the increased public pressure to use lakes and reservoirs with the attendant technical and biological problems that have evolved.

Dean Cliver then elaborated upon the viral element of this microbial water quality concern and described the sources, modes of transmission, and relative public health risks of viral contamination of water.

Having described the water quality problem, the discussion then moved to management implications for limnologists, water specialists, recreationists, and riparian homeowners. Don Johnstone discussed his studies of the bacterial effects of lake alum treatments and of sediment coliform disruptions by dredging. He included recommendations for protecting swimmers' public health as such activities proceed.

George Gibson then described the potential and observed microbial effects of fecal contamination associated with boating, lakeshore housing, and similar land uses in nearshore areas of both lake and estuarine environments. He discussed appropriate monitoring, management, and institutional approaches to the issue.

Following and during these presentations, the panelists responded to audience questions and comments and engaged in considerable discussion of the topic.

MULTIPLE USE ASPECTS OF SURFACE WATER RESOURCES AND PUBLIC HEALTH CONCERNS

Edwin E. Geldreich

Drinking water from impoundments is the source water for about 7,169 municipalities serving more than 55 million people or about 30 percent of the U.S. population served by public water systems.

Originally, it was believed that the only real public health water quality concern should be prohibiting human impacts upon and thus pollution of these watersheds. "Protection" was essentially the only real need for water quality management. Beginning in the late 1800s and early 1900s, the primary strategy for water quality management of public surface water reservoirs was simply to exclude as many people as possible from the watersheds, and fence the reservoirs themselves. If this was done, a level of raw

water quality was assumed which was amenable to fairly simple treatment schemes before distribution. In many instances, treatment by disinfection was the only microbial barrier employed.

Identification of *Giardia lamblia* in drinking water supplies has since proved this time-honored premise wrong. This protozoan is endemic in wildlife populations such as beaver, and perhaps coyotes, muskrats, and voles; it may be in cattle and other domestic animals. We now know it can be transmitted in drinking water supplies regardless of human contamination. Birds and waterfowl are also sources of pollution. Seagulls are scavengers that frequent open garbage dumps and can contribute *Salmonella* in their fecal droppings to lakes within their range. In one instance, seagulls contributed *Salmonella* to an untreated water supply reservoir in an Alaskan community and caused several cases of salmonellosis (Anon., 1954).

Now surface water supplies are recognized as requiring not only the originally conceived protection from human perturbation, but also should be filtered to intercept the *Giardia* cyst and disinfected before distribution to protect against other nonhuman risk sources such as *Salmonella* and viruses. The U.S. Environmental Protection Agency's Office of Drinking Water Research is expected to recommend this procedure for all U.S. surface water supply systems within the coming year. Fifty-nine systems have already adopted filtration and disinfection, but New York City and Seattle, Wash., still justify the use of disinfection alone.

Public health recreational concerns on these reservoirs, lakes, and other surface waterbodies are now recognized as being similarly more complex than originally perceived. Pathogenic ingestion of polluted swimming water is now recognized as not being the only problem. Further investigation is needed to provide information on other body contact hazards from simply being immersed in the water. Enteric organisms are not the only risk. Skin, ear, eye, vaginal, and urinary infections and irritations transmitted through the water from other swimmers are also matters of public health concern. Further, nutrient-enriched recreational surface waters may be a factor enhancing microorganism survival that could considerably expand the health risk of exposure.

VIRAL ASPECTS OF SURFACE WATER QUALITY

Dean O. Cliver

Viruses are transmitted in the aquatic environment in the form of particles much smaller than bacteria. They are totally inert outside of their host; therefore, while there can be waterborne transmission, there is no replication even in the most nutrient-rich aquatic system. The enteric waterborne viruses of human health concern are almost exclusively of human intestinal origin and are very species-specific. Viruses are inactivated by heat, strong oxidizing agents such as chlorine, ultraviolet radiation, and by biodegradation by the normal heterotrophic bacterial community in the water and sediment.

The human intestinal viruses are most frequently transmitted by person-to-person contact. Water, as mentioned, is also an active vehicle for transmission of many of the enteric viruses. Those viruses most frequently waterborne include hepatitis A; the Norwalk-like agents and rotaviruses, which cause gastroenteritis; and enteroviruses other than hepatitis A, which cause upper respiratory infections in swimmers. The principal targets of waterborne viruses are those users involved in primary contact recreation such as swimming, skin diving, water skiing, and, to some extent, fishing. Of course, the largest risk is to those who drink contaminated water, whether it is untreated surface water or surface water that has had minimal treatment (disinfection only). The recommendation for communities using surface water as source water is that filtration and disinfection afford the minimum appropriate level of treatment. There is some concern for those who eat fish from virus-contaminated water, but this route of infection has not been proven.

Waterborne viruses do cause human illness in the United States. In general, the major source of waterborne virus is ultimately human fecal contamination. Therefore, direct fecal contamination from one swimmer to another swimmer via water is the most prevalent mode. Secondary fecal contamination of water, e.g., by boats that do not have adequate on-board holding facilities, is also a problem. Viruses also enter recreational waters through improper operation of nearshore, onsite waste disposal systems. Once the virus reaches the saturated zone, lateral migration is relatively uninhibited and the virus will move with the body of ground water. Once the ground water intersects surface water, the viruses that survived can infect a susceptible host. Generally, the principal reason for viruses entering the saturated zone is that the vadose zone was insufficient for adequate treatment. Point sewage sources are generally not of concern if the discharging communities provide proper secondary wastewater treatment followed by disinfection. Wisconsin is contemplating relaxing disinfection requirements for treated wastewater effluents during cold weather months when primary contact is not an issue. Such wastewater should be discharged as a point source only to recreational waters used seasonally, and not to water that serves as a source for a community supply. Another source of viruses that should not be ignored is runoff from land disposal sites receiving wastewater and sludge.

IN-LAKE/RESERVOIR MANAGEMENT ACTIVITIES AND THEIR EFFECT ON FECAL COLIFORMS: SOME CONSIDERATIONS FOR MANAGEMENT

Donald L. Johnstone

Alum treatment and dredging are two in-lake management operations that can potentially affect water column concentrations of fecal coliforms. The questions are: (1) Does alum treatment and dredging reduce or exacerbate microbiological problems? (2) What management or treatment strategy can be implemented to address potential problems associated with alum treatment and dredging?

Alum treatment of Liberty Lake was accomplished in 1980. Fecal coliform populations were monitored at surface, mid, and bottom depths before and after treatment (Bulson et al. 1984). Prior to alum application the background concentration of fecal coliforms averaged approximately 20/100 ml. One day after treatment, fecal coliforms were reduced to less than 1/100 ml at the surface. As the alum floc formed and settled to the bottom, it carried the fecal coli bacteria with it. Four days after treatment the numbers of fecal coliforms at the bottom increased to approximately 2,900/100 ml as a result of floc concentration. The population of fecal coliforms at the bottom began to decline at three weeks. After the floc was on the bottom, there was some apparent drift as indicated by detection of increased numbers of fecal coliforms on the bottom in the end of the lake that was not treated (control). In general, the floc appeared to remain confined to the deeper portions of the lake and out of the littoral zone. However, if floc containing the high concentration of fecal coliforms drifts into the littoral zone, there is potential for a violation of

recreational water quality standards, and a risk to swimmers.

Alum treatment is very effective in reducing fecal coliform populations from the water column and concentrating them on the bottom. Potentially the pathogens are also removed and concentrated on the bottom by the same mechanisms. Therefore, if there is a chance that the floc may drift into shallow areas used for contact recreation, then the nonrecreational seasons should be considered a more appropriate time for alum treatment. If the nonrecreational season is not a viable alternative, the restriction of use of shallow areas during and for several weeks after treatment should be considered. The period of restricted use would be determined by periodic monitoring of the swimming areas. When anticipating alum treatment for nutrient reduction in a lake, attention should be given to extensive monitoring of fecal coliform populations even in lakes with low bacterial concentrations, since numbers well within accepted water quality standards will probably show high concentrations in alum flocs.

Dredging in lakes and reservoirs resuspends sedimentary fecal coliforms and may cause a violation of standard until sedimentation again removes the fecal coliforms to bottom sediments.

Several investigations have shown the numbers of fecal coliforms in the sediment may be a thousandfold higher than the numbers of fecal coliforms in the overlying water, depending upon the water and the uses it receives (Grimes, 1975, 1980; Stephenson and Rychert, 1982). The relationship between numbers of fecal coliforms in the water and the number of water samples positive for *Salmonella* has been established (Van Donsel and Geldreich, 1971). Generally when the fecal coliforms are less than 200/100 ml, the frequency of isolation of *Salmonella* from that water drops to 28 percent or less. As the number of fecal coliforms increases from 201 to 1,000/100 ml the frequency of *Salmonella* that can be isolated from the water increases to 98 percent of the time (Van Donsel and Geldreich, 1971). Dredging can cause resuspension of fecal coliforms and temporary violations of fecal coliforms standards for recreational water.

Because dredging will temporarily increase the numbers of fecal coliforms when sediments are resuspended, the following points should be considered:

1. Dredge during the nonrecreational season.
2. Use "sea curtains" to help isolate the dredge area from the rest of the water body.
3. Restrict recreational use in the area affected by sediment disruption until clarity is restored.

These precautions are indicated because fecal coliforms in the sediments generally exceed those in the water column and the numbers of fecal coliform in the water column and sediment do relate to the frequency of isolation of *Salmonella*.

PUBLIC HEALTH MICROBIOLOGY AND RECREATIONAL WATERS

George R. Gibson, Jr.

Microbial contamination from nearshore land uses and boating activities is a problem for inland lakes and estuaries alike. Elevated bacterial counts in surface waters associated with human waste disposal have been documented by Mack and D'Itri for a Lake Michigan marina (1973); by Gibson at Lake Redstone, Wis. (1980, 1985); and by Hopkins (1965) and Lear (1966) in Chesapeake Bay tributaries.

Sources of such microbial contamination are typically septic tank system effluents, agricultural runoff from livestock impoundments, and overboard discharge of boat toilets.

Simply stated, Public Health standards indicative of the risk of disease are counts higher than 200 fecal coliform colonies per 100 ml of sample for safe body contact recreation. Similarly abstracted, the U.S. Public Health Service standards for shellfish harvesting require closing beds when the total coliform count exceeds 70 per 100 ml by the "Most Probable Number" technique (MPN) or 14 fecal coli per 100 ml (MPN). Human health concerns associated with these standards are risks of gastroenteritis, ear, upper respiratory, and genitourinary infections as well as particular waterborne diseases such as salmonellosis.

In their 1964–65 studies, Hopkins and Sanderson monitored coliform MPN at a popular marina near the Chesapeake Bay before, during, and after boating concentrations for the Independence Day weekend. They recorded a range from 3/100 ml to 4,300/100 ml in 1965. While the peaks occurred during boating concentrations, it was not possible to distinguish the effluent from the boats from marina or nearby residential septic system discharges. Lear in 1966 conducted a similar study at a yacht club rendezvous with "before, during, and after" sampling. Total coliforms increased from essentially negative to a range of 200–800/100 ml (MPN) as the weekend progressed and the number of boats increased. He, too, stated that shoreside loadings could have been a factor.

An important point here is that contamination of recreational waters often used for swimming was demonstrated presumably by both boats and nearshore septic tanks. Gibson and Cliver demonstrated the movement of bacteria and viruses from septic systems to lake waters in the Lake Redstone, Wis., study.

Lake and reservoir managers therefore should certainly include microbial sampling as a part of their water quality investigations. Fecal and total coliform testing should be routine in body contact or water supply lakes and reservoirs. The membrane filter technique as compared to MPN is the more field-adaptable method for relatively clear waters. Sampling should bracket peak recreational times and locations, and, when possible, an attempt should be made to distinguish the sources. For example, specific identification and sampling of nearshore septic system effluent plumes to a waterbody would help distinguish that source from subsequent boating activities in the area later.

When microbial water quality problems are identified and the sources distinguished, management options include the following:

1. Upgrade or replace nearshore failing septic systems.
2. Install appropriate marine sanitation devices or holding tanks on boats in lieu of overboard discharge toilets.
3. Provide pump-out facilities for the holding tanks, and restrict the number of vessels authorized per unit of time at troublesome anchorages or moorings.

Accomplishing substantive management activities such as those described depends upon the cooperation of the voter, recreationist, and maritime communities. To this end, educational programs on microbial water quality and public health should be extended to these audiences. In particular, boaters and cottagers could be reached by brochures and community information programs.

With popular support, management efforts can be further enhanced by restrictive land use legislation for the nearshore areas of valuable or sensitive waterbodies. Examples of this type of helpful land use regulations are the

Wisconsin Shoreline Protection Act, the Maryland Sedimentation and Erosion Control Laws, and the proposed Chesapeake Bay Critical Areas legislation for Maryland tidewater areas.

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